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EFFECTS OF SIMULATED SURFACE EFFECT SHIP MOTIONS ON CREW HABITABILITY—PHASE II

VOLUME 5. CLINICAL MEDICAL EFFECTS ON VOLUNTEERS.

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20 ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

From July through September 1975, a series of motion simulation experiments was conducted on the ONR Motion Generator at Human Factors Research, Inc. Goleta, California. The motions were based on the mathematical model for the 2000 ton surface effect ship (2000T-SES). Nineteen volunteer human research subjects, selected at different times from 600 naval enlisted recruits, briefed on NAMRL Detachment research, were exposed to several motion profiles. These subjects were extensively evaluated before acceptance. Those with any medical defects which would place them at extra risk of injury while undergoing biodynamic experiments were excluded. Those with anomalous vestibular response were also excluded. The motions to be experienced were those predicted for a 2000T-SES running in a bow quartering sea in 3 separate conditions: (1) sea state three at 80 knots; (2) sea state four at 60 knots; and (3) sea state five at 40 knots. The subjects were to be run in pairs for 48 hours in each of the three conditions. Performance tasks representative of shipboard activities were (over)

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18. SUPPLEMENTARY NOTES (continued)

motion on crew health and performance. Other organizations preparing the companion volumes are Naval Sea Systems Command (PMS-304), Systems Technology, Inc., and Human Factors Research, Inc.

20. ABSTRACT (continued)

administered on a prescheduled basis. The 48-hour motion condition periods were alternated with 48-hour static control periods and 24-hour rest periods. The experimental design called for 12 subjects assuming no voluntary withdrawals. A total of 19 subjects was used, primarily because of volunteer withdrawals following continued emesis. Substantial alterations of the design also occurred due to operational problems with the simulator. For a variety of reasons many runs were undertaken with attenuation of the motion either by a percentage amount or to a selected rms acceleration level. The report is based on 42 runs of varying time duration up to the maximum of 48 hours.

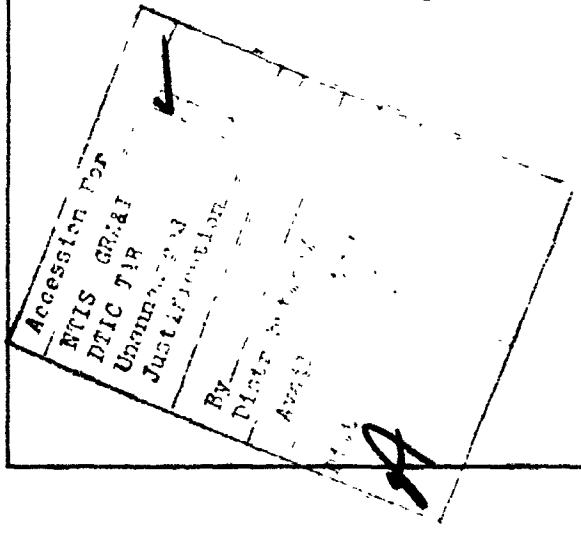
Of the 19 subjects used in these experiments, 14 aborted specific experiments because of vomiting, the extreme stage of kinetosis. Two others aborted an experiment at least once because of continued severe nausea. One subject, used as a substitute on only one run, suffered no ill effects. Therefore, 16 of the 19 subjects aborted because of vomiting or continued severe nausea. Of the 19 subjects, only 2 completed the full series of exposures that had been intended for all subjects. Any subject who once vomited continued to have successive episodes of emesis until the completion of the experiment or until he voluntarily aborted.* Task performance was usually abandoned by the subject once vomiting occurred and often for a variable time preceding actual vomiting. All subjects spontaneously recovered after cessation of the motion. Although rigorous statistical analysis cannot be undertaken, both because of the small sample and because of the many variations of the test conditions, the following findings are presented. In all sea state three simulations, the percentage of subjects vomiting was 22%. This percentage increased to 62% for all sea state four simulations, and further to 73% for all sea state five simulations. These percentages include motion attenuated runs and therefore are conservative estimates of the effects upon volunteers of the predicted motion.

A great deal more medical data was collected but is not included in this report for the reasons noted below. Sleep electroencephalographic data during static and motion conditions was collected and is presently undergoing automated analysis. The linear and angular accelerations of the head were measured in specific orientations but have not been analyzed. Performance and biochemical measurements were made but the data were not available to this facility at the time of writing. Some adaptation to ship motion is known to occur, but studies of this effect were excluded by the experimental design.

CONCLUSIONS

(1) These data indicate that a majority of the subjects tested were able to function for varying periods but were unable to function for the desired period under the tested conditions due to severe continuing kinetosis. (2) There are critical implications of these data for operational use of all seaborne platforms with similar or worse motion profiles.

*This is true in most cases. There were a few subjects in less than 6-hour runs who did not abort after vomiting.



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VOLUME 5
CLINICAL MEDICAL EFFECTS ON VOLUNTEERS

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TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

From July through September 1975, a series of motion simulation experiments was conducted on the ONR Motion Generator at Human Factors Research, Inc., Goleta, California. The motions were based on the mathematical model for the 2000 ton surface effect ship (2000T-SES). Nineteen volunteer human research subjects, selected at different times from 600 naval enlisted recruits, briefed on NAMRL Detachment research, were exposed to several motion profiles. These subjects were extensively evaluated before acceptance. Those with any medical defects which would place them at extra risk of injury while undergoing biodynamic experiments were excluded. Those with anomalous vestibular response were also excluded. The motions to be experienced were those predicted for a 2000T-SES running in a bow quartering sea in 3 separate conditions: (1) sea state three at 80 knots; (2) sea state four at 60 knots; and (3) sea state five at 40 knots. The subjects were to be run in pairs for 48 hours in each of the three conditions. Performance tasks representative of shipboard activities were administered on a prescheduled basis. The 48-hour motion condition periods were alternated with 48-hour static control periods and 24-hour rest periods. The experimental design called for 12 subjects assuming no voluntary withdrawals. A total of 19 subjects was used, primarily because of volunteer withdrawals following continued emesis. Substantial alterations of the design also occurred due to operational problems with the simulator. For a variety of reasons many runs were undertaken with attenuation of the motion either by a percentage amount or to a selected rms acceleration level. The report is based on 42 runs of varying time duration up to the maximum of 48 hours.

Of the 19 subjects used in these experiments, 14 aborted specific experiments because of vomiting, the extreme stage of kinetosis. Two others aborted an experiment at least once because of continued severe nausea. One subject, used as a substitute on only one run, suffered no ill effects. Therefore, 16 of the 19 subjects aborted because of vomiting or continued severe nausea. Of the 19 subjects, only 2 completed the full series of exposures that had been intended for all subjects. Any subject who once vomited continued to have successive episodes of emesis until the completion of the experiment or until he voluntarily aborted.* Task performance was usually abandoned by the subject once vomiting

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EFFECTS OF SIMULATED SURFACE EFFECT SHIP MOTIONS ON CREW HABITABILITY — PHASE II

INTRODUCTION

The Surface Effect Ship Project Office (SESPO) has conducted three motion simulation efforts since September 1973. The medical effects from the initial effort at the Marshall Space Flight Center, Huntsville, Alabama, have already been reported (1, 2). Those reports pertain to an attempt at simulating the motion of the 100 ton Surface Effect Ship (SES) for durations up to two hours. The medical effects from a second study, conducted at Human Factors Research, Inc. (HFR), Goleta, California, have been reported also (3, 4). A final overall report has been prepared for SESPO by Systems Technology Inc. (STI), Hawthorne, California (5). That effort conducted in August and in October 1974 (Phase I and Phase IA) involved simulation of the heave motion (with some associated pitch and roll) anticipated aboard a 2000 ton (2K) SES for durations up to 48 hours. However, simulator limitations prevented the full simulation of heave motion. After Phase IA, considerable improvements were made in the capability of the device so that it could more fully simulate the anticipated heave motion of the 2K SES. A third effort (Phase II) was thereupon undertaken by SESPO to simulate the full anticipated heave, pitch and roll motions of the 2K SES for 48 hours using volunteer subjects in three selected motion conditions. The Phase I, IA and II studies were conducted on the Office of Naval Research motion generator (MOGEN) at HFR. The present report describes the medical effects of the Phase II simulations upon the volunteers. Phase II experimentation ran from 14 July 1975 to 2 October 1975.

EXPERIMENTAL METHOD

A. Schedule

The original experimental schedule of Phase II was divided into three segments. The intent of each segment was to run sequentially two different two-man crews through sea state 3, 80 knots (SS3), sea state 4, 60 knots (SS4) and sea state 5, 40 knots (SS5), for forty-eight hours in each condition. All conditions had a bow quartering sea (135°). The forty-eight hour periods were preceded by two days of subject testing in a control condition and a one day pause for equipment maintenance at which time the subjects were free for rest and relaxation, Fig. 1. The simulation for each sea state include heave, roll, and pitch for the modeled 2K SES at the center of gravity. The control condition was designed to be identical to the motion condition. A stationary control test cabin adjacent to

the motion device was used. When one two-man crew was in motion, another two-man crew was in the control condition. Nominally, twelve subjects would have been used presuming no dropouts. There were short duration orientation runs in the simulator and limited training sessions for task training. For a variety of reasons there were marked departures from the projected schedule which was established and modified several times by SESPO. The actual run chronology is listed, Fig. 2. Also, a total of 19 subjects were used instead of 12, primarily because of subject dropouts due to repeated emesis.

B. Activity Cycle

A wide variety of tasks was administered to simulate various aspects of anticipated SES shipboard activity. These tasks were sequenced into a carefully structured twenty-four hour cycle of work, rest, and sleep for each crew member. Within each crew one subject was designated as a night sleeper (2400 to 0800 hours) and one a day sleeper (1200 to 2000 hours). Adaptation to the day sleep cycle was attempted by requesting day sleepers to assume the cycle 24 hours before the start of the simulation and to maintain the cycle on days off. However, no attempt at rigorous enforcement of day sleeping was undertaken. The details of this cycle were controlled by HFR. The details of execution and analysis of the performance testing are available from HFR and STI. Many of these tests had been administered previously in Phase I and IA (5).

C. Recruitment Procedures

The volunteer subjects used in Phase II came from a series of recruitment efforts listed and summarized in Fig. 3. After a bulletin board advertisement of the program at the Recruit Training Command, Orlando, Florida, a presentation was made to interested recruits as a group (presentation group) after normal working hours. As a result of the presentation those with a continuing interest were immediately interviewed (interview group). On the basis of the interview a volunteer candidate group was identified. Initial screening of this group was conducted within 24 hours by review of dental, medical, and administrative records, and x-ray examination of the low back. Remaining volunteer candidates reported to the Naval Aerospace Medical Research Laboratory (NAMRL), Pensacola, Florida, for two weeks of intensive medical evaluation. The volunteers were those who, having completed this evaluation, reported to the NAMRL Detachment, New Orleans, LA, where a detailed, unique research medical record was established and is currently maintained. As a result of this process, twenty-six volunteers were qualified for biodynamics research. The twenty-six subjects were a carefully screened and self-selected group from a total of

600 interested recruits. Thus, the overall selection rate for biodynamics research was 4.3%. Nineteen of these volunteers were used in Phase II.

D. Qualification of Human Volunteer Subjects

The volunteer subjects used in Phase II were attached to the NAMRL Detachment and were recruited, evaluated and used in strict accordance with procedures specified in SECNAVINST 3900.39. They perform duty as experimental subjects utilizing experimental acceleration or deceleration devices. Since all the experimental protocols call for the use of such experimental devices, the subjects were qualified for hazardous duty pay under the provisions of public law. The detailed medical qualification of each individual subject therefore assumes paramount importance. These qualifications are considerably more stringent than the normal medical qualifications for military service or for various other categories of experimental stress duty. In effect, each particular subject must be demonstrated to be free of any defect that would increase his susceptibility to injury under this specific experimental stress, before the subject is ever used in an experiment.

The examination was conducted by the staff of the Naval Aerospace and Regional Medical Center (NARMC), in the Naval Aerospace Medical Institute (NAMI), and NAMRL, Pensacola, Florida. It was organized according to specific specialty consultations. The consultations required are as follows:

1. Dental evaluation, with full x-ray examination of all teeth to determine the quality of bite, the status of each individual tooth and its root structure. This is required in order to determine that there is an adequate dental, gingival and bony base to support the specialized anatomical mount that holds the inertial instrumentation used in the experiments.

2. Internal medicine examination by a board qualified specialist. This includes:

   (a) Standard 12 lead electrocardiogram with the volunteer fasting and rested.

   (b) Exercise electrocardiogram according to the Bruce protocol (6).

   (c) Vectocardiogram, utilizing the Frank lead system (7).

(d) Pulmonary function studies with determination of forced expiratory volume (FEV), forced expiratory volume in one second (FEV1), percentage ratio of FEV to vital capacity (VC), maximum expiratory flow rate (MEFR), maximum mid expiratory flow rate (MMEFR), and maximum voluntary ventilation (MVV). A standardization group is available (8).

(e) Blood chemistries using the SMA-19 profile which includes calcium, inorganic phosphate, glucose, blood urea nitrogen (BUN), uric acid, cholesterol, total protein, albumin, total bilirubin, alkaline phosphatase, lactic dehydrogenase (LDH), serum glutomic oxaloacetic transaminase (SGOT), sodium, potasium, chloride, carbon dioxide combining power (CO_2), creatinine, serum iron, triglyceride, and 2 hour post prandial blood sugar. In addition, the beta, pre beta, and alpha lipoprotein fractions are determined in selected cases.

(f) Hemogram, which includes hemoglobin (Hgb), hematocrit (Hct), red blood cell count (RBC), total white blood cell count (WBC), differential WBC, platelet count, prothrombin time (Pro time), and partial thromboplastin time (PTT).

(g) Urinalysis, which includes appearance, specific gravity, pH, protein, glucose, acetone, occult blood, and microscopic examination of the urinary sediment after centrifugation.

Further testing or consultations are conducted as required in the individual case.

3. Electroencephalographic examination with interpretation by a neurologist. The examination included an effort to elicit latent seizure activity by hyperventilation and/or photic driving.

4. Ophthalmological examination under the supervision of a board qualified specialist. Visual acuity, manifest refraction, tonometry in indicated cases, and visual fields with the Goldman perimeter were recorded. Five photographic views of each fundus, centered on the optic disc, were obtained.

5. Orthopedic examination by a board qualified specialist including review of the x-rays of the skull and of the entire vertebral column.

6. Ear, nose and throat examination by a board qualified specialist with indirect laryngoscopy. Any variation of airway structure was carefully evaluated. The external auditory canals were examined and cleaned prior to audiometric examination.

7. Detailed audiological examination by the Acoustical Sciences Division, NAMRL. The tests conducted were pure tone audiogram, speech audiometry, and tone decay test.

8. Psychological evaluation by the Personnel Research Division, NAMRL. The specific personality tests were Guilford-Zimmerman Temperament Survey, Eysenck Personality Inventory and the Taylor Modified Anxiety Scale.

9. Psychiatric consultation and interview by a board qualified psychiatrist or a clinical psychologist under his supervision. In addition to a standard clinical psychiatric interview, the Bender-Gestalt test, the Minnesota Multiphasic Personality Inventory (MMPI), and the Graham-Kendall Memory for Design Test were administered to each candidate.

10. Ataxia testing was performed using a rail test battery of: walk-3/4"-wide-rail-eyes-open (walk E/O), stand-on-3/4"-wide-rail-eyes-open (Stand E/O), stand-on 2-1/4"-wide-rail-eyes-closed (Stand E/C), and a floor test battery of: sharpened Romberg (SR), stand-one-leg-eyes-closed (SOLEC R&L), walk-on-floor-eyes-closed (WOFEC). These tests and results of the standardization group are described (9, 10, and 11).

11. Detailed consultation by the Perceptual and Behavioral Sciences Division NAMRL for the purposes of specific testing of the vestibular system. The specific examinations conducted are listed and described (12), along with the reports for each subject used in Phase II. The results of the VVI, SVDT, MSQ, and PATE were used in an attempt to rank susceptibility to motion sickness. Detailed description of each test and partial standardization group data are available (13, 14, 15, 16, and 17).

12. Additional vestibular function testing by the Physiological Optics Division, NAMRL. The counterrolling index, oculogyral illusion, cold and hot caloric threshold and Fitzgerald-Hallpike scores were developed from the tests. Description and application of the tests are available (18, 19, 20, and 21).

13. X-ray examinations as listed:

(a) Posterior-anterior (PA), anterior-posterior (AP), right and left lateral of skull and open mouth adontoid process view.

(b) A-P lateral, left and right oblique, hyperextension and hyperflexion of cervical spine.

(c) A-P chest.

(d) A-P and lateral thoracic spine.

(e) A-P standing, recumbent lateral, left and right oblique of lumbo-sacral spine, and coned down view of the lumbo-sacral junction.

In this series of detailed examinations, each abnormality which was detected was carefully documented. A judgment was then made concerning the significance of this abnormality with regard to the fitness of each volunteer candidate subject. In individual cases further medical consultations may be required. The variations from normal for each subject used in Phase II are listed, Fig. 4.

E. Medical Monitoring Procedures

Medical monitoring was carried out on a 24 hour per day basis by physicians from NAMRL Detachment; Naval Hospital, Bethesda, MD; and Naval Medical Research Institute, Bethesda, MD. A medical officer was at the test site at all times while the simulator was in motion with a human subject aboard. This required two medical officers in the Goleta area at all times during the 48 hour simulations. The medical officers from the NAMRL Detachment had extensive professional knowledge of each volunteer subject, supported by detailed medical records, as a result of the human subject selection procedures, and utilization of the subjects for impact acceleration experiments. Reference 22 is a computer listing of the impact acceleration experiment experience for each subject prior to September 1975 giving the run number, sled peak acceleration in G's, sled acceleration rate of onset in G's per second (onset) and sled acceleration duration above 75% of peak in seconds. Seven subjects had run to 15 G's, three subjects had run to 10 G's, two subjects to 6 G's and seven subjects to 3 G's. The subjects' repeated experience in impact experimentation indicates effective motivation to continue in hazardous and stressful research.

The primary record of observation was the medical log (23), in which all of the on-site medical observations were recorded. These observations include the pre-run and post-run medical examinations. The tabulation of the runs is abstracted from the medical log and organized by date and subject, Figs. 2 and 5.

Secondly, electrophysiologic measurements collected during selected periods of observation were recorded on magnetic tape. These records consisted of one channel of electroencephalogram, two channels of electrooculogram, one channel of electromyogram from the neck, and two channels of head acceleration used in the analysis to control for motion artifact. This was recorded on every subject during his sleep cycle in the control and in the motion conditions. The complete commanded and measured accelerations of the cab were recorded during the sleep cycles. The data will be subjected to automated analysis by a Frost Analyzer system (24) and will be the subject of a separate report. Various segments of a one channel electrocardiogram were recorded on demand by the medical officer for clinical observation. These records were not subjected to any systematic analysis since no abnormalities were noted. In Phase I, a cardiac arrhythmia had been detected on one subject suffering from kinetosis (3, 4).

The third monitoring procedure consisted of the measurement of head accelerations using a mouth-mounted T-plate carrying six accelerometers separate and distinct from the two accelerometers mentioned above (25, 26). The purpose of the measurements was to determine the inertial response of the head to the cab motion and to determine whether there was any postural control of the head by the subject in response to the feelings of motion sickness. The need for this information is presented in the discussion. The position and orientation of the accelerometers relative to the head anatomical coordinate system, the position and orientation of the head relative to the cab, the designated bow direction of the cab and the heave, pitch, and roll of the cab at the time of the measurement are all known and recorded. Therefore, the inertial input to the labyrinth system can be computed using an estimate of the location of the labyrinth relative to the head anatomical coordinate system derived from 3D x-ray anthropometry on each subject. The measurements were scheduled every 12 hours on each subject in motion. Three orientations related to the roll and pitch axes of the cabin were used:

(a) Five minutes sitting, facing the east wall of the cabin (starboard).

(b) Five minutes sitting, facing the north wall of the cab (bow) (contains the door).

(c) Five minutes standing, facing the east wall of the cabin (starboard).

Cabin axes are drawn, Ref. 5, pg 40, in which the front of the cabin is coincidental with the bow of the 2K SES.

Occasional modifications of the time and/or orientation were necessary. If the subjects were complaining of motion sickness symptoms that might be aggravated by the presence of the mouth mount, the measurements were abandoned. If during the course of taking the measurements motion sickness symptoms were aggravated the measurements were stopped. One subject, 47, vomited toward the end of a measurement series, requiring emergency removal of the mouth mount. The analysis of the head inertial measurements is to be reported separately.

The fourth monitoring procedure was included as part of the subjects' task performance. Each subject periodically recorded the blood pressure of his crew partner. Periodically each subject also measured and recorded his own oral temperature. These records were compiled by HFR. Review by the medical staff, NAMRL Detachment, revealed no significant changes. In addition, 24 hour urine collections for catecholamines were accumulated by HFR. Periodic urinalyses were done on small aliquots, before their addition to the 24 hour collection, and were recorded in the medical log.

RESULTS

The clinical observations are contained in the chronological medical log (23). This log is summarized by date, Fig. 2. The summary presents the incidence and time to emesis and to voluntary abort for each run. Emesis is generally considered to be the most severe stage of kinetosis. Its occurrence is the most readily observed and recorded criterion of kinetosis. However, there are many other important and severe symptoms of motion sickness, which may be more disabling than vomiting in individual cases. A comprehensive review of these symptoms was published by Money (27). Most of the subjects used in the present experiments displayed a wide variety of motion sickness symptoms. Most of those who aborted runs did so after vomiting. The two subjects who aborted but never vomited were suffering severe kinetosis as evident from other symptoms. Comments on the salient features of the individual runs are included in the remarks column of Fig. 2. Each run should be considered in order and by subject due to the fact that various levels of motion attenuation and various time durations from 2 hours to 48 hours were used for each sea state. Also, the response to vomiting and the symptoms associated with vomiting varied from subject to subject. The constellation of associated symptoms includes:

(a) Lassitude
(b) Anorexia
(c) Dizziness
(d) Headache
(e) Intermittent nausea usually temporarily relieved by vomiting.

There were certain features of the syndrome of motion sickness, common to all, which were:

1. During runs planned for more than 6 hours duration, a subject who once vomited continued to vomit or have other symptoms of kinetosis until he aborted the run.

2. A volunteer who vomited, or was in the prodromal stages of vomiting or was attempting to alleviate the feelings of motion sickness, would sooner or later abandon his scheduled performance tasks.

3. Cessation of the motion alleviated the symptoms in all cases. The time for complete alleviation of symptoms varied from a few minutes to twelve hours in individual cases. However, with one exception, no subject vomited after the motion was stopped. Subject 50 on one occasion induced vomiting in himself shortly after descending from the moving cabin, maintaining that he felt he had to do this to feel better, Figs. 2 and 5. No medical treatment was administered by the physicians with the exception of aspirin for headache.

4. There was no evidence of habituation within any of the runs in which vomiting occurred.

5. Kinetosis was the only reason for voluntary subject aborts.

The most severe case of repeated vomiting occurred on the run of 7/20-21/75, condition SS3, subject 47. The subject vomited 10 times within about 23 hours and finally voluntarily aborted the experiment. The major medical findings were hemoconcentration (hemoglobin 16.3 gm/dl), and urine concentration (specific gravity 1.037) with 2+ protein in the urine, indicative of renal stress. This was considered to be due to clinical dehydration; however, an anti-diuretic hormone effect is possible (27). The pre-run weight was 170½ lb. An immediate post run weight was not obtained. After a 2½ hour recuperation period, he weighed 166 lb. Despite the protracted stress and having eaten a substantial meal about two hours after the run he recovered promptly and completely without treatment.

For the purposes of these experiments subject 58 must be considered as a separate case. It should be noted that he ran as a substitute subject in SS5, 9/1/75 for 2 hours and 47 minutes before he aborted. During this time he vomited 6 times. He had no significant experience at lower sea states due to a gastroenteritis of 7 to 10 days duration. This illness prevented him from participating in his planned runs in lower sea states. He had only recently recovered before his use as a substitute in SS5. This is the only case in which the prior medical condition of the subject interfered with the scheduling of the subject or may have reduced his tolerance to motion sickness.

The experiences of two other subjects warrant individual consideration. Subjects 38 and 46 were used in SS3 and SS4 runs and never vomited. However, they did abort SS3, 7/30-31/75, due to severe nausea. Subject 38 was gagging and coughing at time of abort although he did not actually vomit. Subject 46 voluntarily withdrew because of severe nausea, regurgitation and sensation of whole body "tumbling" while in the bunk trying to sleep.

There was one other subject who aborted two runs without vomiting. Subject 50 vomited and aborted his first and second runs in the 0.3 Hz, 0.19 G rms sine wave condition. On his next run he aborted the same level run without vomiting, primarily due to sensations of "spinning". He also aborted a SS5 run due to the feeling of impending vomiting and "everything spinning around".

The incidence of vomiting and voluntary aborts is listed by subject in each run, Fig. 6. The interpretation of any percentage incidence derived from this table will be affected by:

(a) The extensive variation in the run duration which ranged from 1 hour and 42 minutes to 48 hours.

(b) The extensive variation in the time an individual subject spent in an individual run which varied from 23 minutes to 48 hours. This variation was caused by voluntary aborts or mechanical breakdowns. There was one case in which a subject ran for only 30 seconds because of a machine failure. This is not included in Fig. 6 and should be excluded from computation of any percentage.

(c) The extensive variation in the acceleration amplitude of the nominal sea state which was accomplished by reducing the commanded heave acceleration to a range of 64% - 100% of the full sea state.

Other modifications of the nominal sea states were caused by running with only one hydraulic heave pump in operation and one run in which roll and pitch were not commanded.

(d) For each crew, one subject was on the day sleep cycle and the other on the night sleep cycle. This was further complicated when replacement subjects continued the cycle of a subject who voluntarily aborted. Also crew pairing was not constant.

(e) The order in which a subject experienced the sea state, usually progressing from lower to higher, may have introduced an adaptation variable, the effect of which cannot be evaluated.

The complex and specialized nature of the SES model and the major sources of variation suspected to affect the emesis and voluntary abort percentages preclude generalization of these results to other motion conditions of a different vehicle, time duration, activity cycles, or adaptation state.

The overall incidence of emesis by the subjects in different conditions is summarized in Fig. 7. The overall incidence of abort by the subjects is summarized in different conditions in Fig. 8. It should be noted that the incidence is reported by motion condition regardless of attenuation or the number of runs a subject experienced at each condition. Partitioning the incidence by sea state and attenuation would result in too few subjects in different conditions to formulate meaningful percentages. Therefore, if unattenuated sea state motions were used in all conditions, higher percentages of emesis or aborts may have resulted. The sine wave condition was used at a time when the sea state motion was not available and is listed separately.

Overall, 14 of the 19 subjects vomited at least once, leaving two subjects who were able to complete the full SS3, SS4, and SS5 experimental schedule, one alternate subject whose only run, SS3 for 23 hours, was successfully completed without vomiting, and two remaining subjects who aborted their runs because of severe kinetosis without vomiting. A summary of the number of runs, running times, and the runs in which emesis or volunteer abort occurred is given in Fig. 9. Vomiting or volunteer abort without vomiting occurred in 23 of the 42 runs.

An attempt was made to rank each subject for susceptibility to motion sickness induced by the simulation, Fig. 5. Two criteria

were sequentially applied. The first criterion was that the subjects who first vomited in a lesser numbered sea state run were considered more susceptible than those who vomited in a higher numbered sea state. This partitioned the subjects into those first vomiting in SS3, SS4, or SS5. The second criterion was that, within each sea state, a subject was considered more susceptible based on the time to first vomiting. On this basis it was possible to rank 17 of the 19 subjects. The apparent equal ranking between subjects 43 and 51, who did not vomit, was resolved on the basis that subject 51 experienced slight nausea. The experience of each subject is summarized, Fig. 5. The subjects are arranged in descending order from the most to the least susceptible. Subjects 35 and 58 could not be ranked and are excluded.

A composite score of the VVI, BVDT, MSQ, and PATE tests (12), was compiled by Dr. Fred Guedry, NAMRL, Pensacola, Florida, and is given in Fig. 10. Only 15 subjects were ranked by this test procedure. The hypothesis was, that the higher the total standard score, the greater the susceptibility to motion sickness. A rank correlation analysis of the motion sickness susceptibility prediction, Fig. 10, with the actual susceptibility ranking, Fig. 5, was done on the 15 subjects common to both lists. The Kendall-Tau correlation coefficient was calculated and found to be 0.37 which is significant at the 5% level. Also, the Spearman Rank correlation coefficient was calculated and found to be 0.42 which is significant at the 10% level. The conclusion from this analysis is that there is a suggestion of a weak relationship between the two methods of ranking. However, its use in its present form as a method of predicting susceptibility to low frequency motion sickness exposure would be highly unreliable.

Figure 11 lists the elapsed time in ascending order to first vomiting and to abort, with or without vomiting. The extremes range from 15 minutes to 12 hours 30 minutes. Therefore, the two-hour runs used for the motion sickness incidence (MSI) curves would not be sufficient for further studies of the complete incidence of motion sickness induced by the anticipated 2000 ton SES motion (28). Also, in studies of two hours duration and beyond, a substantial portion of the subject group could be expected to experience cumulative stress from early or repeated vomiting.

The sleep assignment of the subject for the particular run is indicated, Fig. 11. Short duration runs are those of planned duration of 6 hours or less. There were 19 instances of first emesis in these short duration runs. There were 12 instances of first emesis in long duration runs. Five occurred in assigned night sleepers and seven occurred in assigned day sleepers. In these

twelve cases 3 night sleepers and 4 day sleepers vomited for the first time after 6 hours. Therefore, about 50% of those vomiting in runs longer than six hours vomited for the first time after six hours. It did not appear to make any difference whether the men assigned were day or night sleepers.

DISCUSSION

The main medical effect of simulation of anticipated 2K SES motion was kinetosis (the syndrome of motion sickness) (27). This was the rule rather than the exception in simulated conditions worse than SS3. Sixteen of the nineteen highly selected volunteers, experienced as subjects in biodynamic experiments, succumbed to kinetosis as evidenced by frank vomiting or by voluntarily aborting the experiment because of other symptoms of motion sickness. Only two of the 19 subjects were able to complete all planned test conditions without emesis. One subject, a replacement volunteer, was not exposed to all conditions during this series. Frank vomiting occurred in fourteen subjects, with repeated episodes in most cases. Despite repeated runs by most of the volunteers who vomited, none was able to complete the full schedule, from SS3 to SS5. The onset of kinetosis not only led to residual symptoms from the motion sickness which could persist for several hours after his removal from the provocative motion, but also disrupted and frequently forced the complete abandonment of the task performance.

It is impossible to avoid drawing the conclusion from these findings that the simulated 2K SES motion as prolonged as in these experiments, at least in sea states worse than SS3, poses a severe threat to the well being of otherwise fit and healthy naval recruits, as well as to their ability to perform their duties at sea.

In the course of the present simulations, there was evidence that susceptibility to kinetosis decreased with continued or repeated exposure to the provocative motion, in other words, no habituation was noted. This particular observation may, however, be an artifact of these particular experiments (see below). As is commonly observed in the field and in experimental studies of motion sickness (28), the main presenting symptoms of the syndrome, including vomiting when it occurs, subside spontaneously and rapidly upon cessation of the motion, without any evident residual ill effects. This is in accord with the consensus based on scientific and general experience that the syndrome is a purely physiological one, i.e., a spontaneously reversible alteration of function, which is not known ever to have led directly to a pathological or fatal outcome (27, 29).

Incidence of Sickness

The incidence of frank vomiting and of aborts due to incipient emesis or related symptoms is shown in Figs. 6, 7, and 8 and has been described in the results. It is apparent that there was a high incidence during simulations of SS4 and SS5: about two thirds of all subject-runs were aborted before completion of the scheduled simulation. By contrast, the incidence was less than one fourth during SS3 simulations. During exposure to an arbitrary, if approximately equivalent level rms acceleration of provocative sinusoidal heave motion, there was again a high incidence, namely, more than half. The levels of rms acceleration in SS4 and SS5, and in the sinusoidal trials were severe according to current draft proposals based on admittedly tenuous data, regarding criteria of human exposure to oscillatory motion in the range 0.1 to 1 Hz. These proposals are under consideration by the International Organization for Standardization (30), and if adopted by ISO, will presumably be embodied eventually in the next revision of MIL-STD-1472B. The motions represented a stimulus 20 to 30 times the threshold levels of perceptual or physiological response to linear acceleration affecting the human vestibular system in the frequency band of interest (27, 29, and 30).

It must be noted, however, that Figs. 6, 7, and 8 pool data from all runs of nominally equal sea state conditions. Yet reference to the experimental log shows that, for one procedural reason or another, the simulations actually carried out in a given sea state (SS3 or SS4, for instance) varied substantially from one run to another, both as regards rms acceleration level and the complexity of the motion. On one run, the motion was restricted to heave alone, without pitch or roll. This fact, together with the multiplicity of experimental variables and frequent departures from the experimental design underlying these studies, rendered statistical treatment of the data of doubtful validity. Hence it can only be said that the various simulations of SS4 and SS5 were associated with a high incidence of sickness of sufficient severity to disrupt task performance or abort a mission, whereas only a quarter of the subjects were forced to abandon tasks or ultimately their mission due to sickness in SS3. As regards motion sickness incidence, the data are insufficient to draw a practical distinction between SS4 and SS5 as simulated in the present study, primarily because of the inability of most subjects to tolerate SS5, thus yielding too little data for comparison. Furthermore, the small size of the subject group available for this study, as well as the absence of any reliable methodology for measuring sensitivity to motion sickness, precluded reliable prediction of individual susceptibility to motion sickness before actual exposure of the subjects to the simulated motion.

Time to Emesis

Figure 11 shows the distribution of elapsed times from the beginning of motion in each simulation to first emesis in each subject. It is seen that elapsed time to emesis varied from subject to subject and run to run in a highly idiosyncratic manner during the simulated SES motion runs, ranging from a little over 15 minutes to more than 12 hours. No clear pattern relating to sea state emerged; and again, the multiplicity of experimental variables in the present studies precluded any analytical search for one. Possibly, in any future study, it might be more informative to record also time to onset of the syndrome (as evidenced by malaise or other presenting symptom rather than frank vomiting), for the onset of vomiting depends upon several factors influencing the rapidity of development of the physiological syndrome, as well as on a degree of conscious control and motivation on the part of the individual subject.

It did appear on the face of it that pure vertical sinusoidal motion, which in rms acceleration was of approximately equivalent severity to that of the higher sea states simulated, but which had a highly provocative frequency of oscillation (0.3 Hz), was associated with a particularly rapid onset of kinetosis, Fig. 11.

The Question of Habituation/Adaptation

A somewhat anomalous finding in these studies was the lack of habituation (or adaptation) of the subjects to the simulated motion: the subjects apparently were not able to benefit from repeated or continued exposure to the motion, either as regards their voluntary tolerance of it or their ability to carry out their simulated mission according to objective criteria. Such a finding, if substantiated, is out of accord with the general body of knowledge concerning motion sickness in man. Substantial evidence, based on scientific observations in field studies at sea and in the air, as well as on anecdote and maritime tradition, indicates that physiological adaptation as well as psychological habituation which influence both performance and the subjective response do occur (27, 31). It is possible, however, that this holds good only for relatively short-lived and moderate motions of the kind natural to conventional craft. Extremely severe and unusual motion, when continuous and prolonged, may preclude habituation. Moreover, even if the severity of the motion were not in itself counter-adaptive, the absence of habituation in these simulations leads one to ponder whether there might not have been some counter-adaptive artifact operating in the present experimental design or conditions. Conscious reinforcement of the subject's awareness of the purpose and endpoint of their exposure to the simulated conditions is of course

likely to have been a strong factor, due to the interaction between subjects riding together, the necessary medical observations and apparatus, and the continuous interrogative contact with the control room.

Motion of the Head and the Vestibular Stimulus

The question of using data from these experiments to draw general conclusions must be faced squarely. There is considerable evidence that the vestibular apparatus and its central nervous system connections are intimately involved in the production of motion sickness. A case in point is the study by Kennedy, Graybiel, et al. (32). In that study, supposedly normal investigators as well as the crew of a sea going tug 145 feet long with 33-foot beam and a displacement of 546 tons, were exposed to severe natural sea states for a prolonged period up to 18 hours, along with an experimental group of individuals who were labyrinthine-defective (L-D). Of the 20 controls including investigators and crewmembers, 15 vomited and the remainder were motion sick. Of the 10 L-D experimental subjects exposed to the same motion at the same time, none vomited or manifested symptoms of the kind considered to be typical of motion sickness.

That study clearly confirmed that a major factor in the production of motion sickness is the inertial or force input to the labyrinthine portions of the vestibular apparatus. In the present study, instrumentation mounts developed under a different program but for a similar purpose, were used to attach inertial measurement devices rigidly to the head, as noted in the description of medical monitoring procedures above. By using previously developed coordinate systems and x-ray anthropometry, it has been shown that the head is or acts like a rigid body and that forces measured by these mounts can be transformed to any point in the bony skull using the equations of rigid body mechanics (25). Thus, it is believed that the inertial forces acting on the labyrinths can be determined with precision, millisecond by millisecond if need be.

Such measurements are crucial because measured forces acting on a ship, or simulator cab, are not necessarily those which prevail at the labyrinths. Coupling of the head to the ship or cab is an uncontrolled variable in all these experiments, and the measurement of inertial input to the labyrinths is the only way to escape the inability to determine the coupling factors or constants.

The ability to measure precisely the inertial forces acting on the ship or cab rather than the man increases the temptation to relate motion sickness to these gross vehicle inputs. This must be resisted, however, because of the lack of knowledge of the coupling of torso to vehicle and head to torso.

Nevertheless, vehicle to vehicle comparisons might be made on the basis of measured input to the man's head and/or labyrinths, since this defines the net coupling of labyrinth to vehicle regardless of the steps in between. The attempted protective means used by several subjects who were affected by motion sickness during these simulations was to attempt to prevent head motion by fixing the shoulder girdle and using shoulder muscles to attempt to dampen head motion.

Measurement of cab motion profiles permits frequency spectral analysis. In these experiments analysis has been performed and the rms acceleration level of each frequency band determined. The frequency spectral analysis of inputs to the labyrinth, however, which is probably a determining factor in production of motion sickness, awaits data reduction of the head-mounted T-plate accelerometer data, which analysis is not funded at present.

Neurological Signs and Symptoms Apart from Kinetosis

Several subjects reported, or were visibly affected by, vertigo and/or postural unsteadiness occurring as a transient phenomenon immediately following cessation of motion. There were also occasional reports of vertigo, that is, sensations of spinning or tumbling during motion, which were important symptoms in those subjects who aborted without vomiting. These cases were recorded in the medical log. The essential features of the disorder were as follows. Vertigo during motion, and in some cases a very specific sensation of horizontal rotation or, more commonly, phantom vertical motion persisting after removal from the moving cabin, were reported at debriefing by a number of subjects. Less frequently, subjects spontaneously reported sensations of postural unsteadiness. In a few instances, the subject was visibly unsteady when descending the steps from the moving cabin within a few minutes of cessation of motion. Several subjects exhibited a positive Romberg sign and other signs of temporary incoordination during the post-run physical examination. In two instances, transient vertical nystagmus was observed by a medical officer immediately following cessation of motion in SS5 in subjects who had completed the 48 hour run without vomiting.

These signs and symptoms rarely developed until the subject had been several hours in motion. However, we have insufficient observations to indicate whether the incidence of such neurophysiological manifestations is related to the severity (rms acceleration level), complexity, or duration of the motion exposure. A systematic scientific study would be necessary to determine the importance of such factors.

The neurophysiological manifestations were invariably transient, lasting from seconds to minutes after cessation of the real motion. It was rare for any symptom or sign of the kind described to persist for longer than 20 minutes, even in cases where the subject still felt generally unwell as a result of kinetosis.

These signs and symptoms were not necessarily correlated strongly, if at all, with the incidence or severity of kinetosis. They were sometimes present to a marked degree in subjects who were not sick or even nauseated, but who had been removed from the moving cabin at the scheduled termination of a run or upon termination of a run for some other reason (e.g., mechanical failure). Conversely, neurophysiological signs and symptoms were as frequently absent or at least unreported in subjects who had vomited. The data that might indicate whether or not the neurophysiological manifestations affect performance independently of the disruption of the mission by kinetosis already alluded to from Phase II are undergoing analysis by HFR and STI. It is conceivable that postural unsteadiness could degrade the performance of a variety of motor tasks, ranging from fine manipulation to locomotion, perhaps increasing the chances of falls or other shipboard accidents.

As in the case of motion sickness itself, the evidence for transient postural phenomena disturbing people after the cessation of real motion is largely anecdotal. Persistent phantom motion (lasting several hours) is quite commonly experienced. It is probably a vestibulocerebellar response, as yet of obscure etiology.

Nystagmus appears to be a new finding in the present studies, not to our knowledge previously reported in motion studies without rotation of the subject. Razumeyev states categorically that nystagmus is not associated with the kinetosis syndrome (29). Possibly nystagmus is a rare and transient manifestation of vestibular stimulation due to oscillatory motion; and, accordingly, easily overlooked. At present, its significance remains obscure. It should be noted however that direct heave motion of the cab does result in continuous rotational oscillation of the unsupported head in the mid-sagittal plane, and this may be related to the development of vertical nystagmus.

CONCLUSIONS

1. Sixteen of 19 subjects could not complete the experimental protocol because of severe kinetosis evidenced either by vomiting or refusal to continue the run.

2. SS4 and SS5 were substantially more provocative of kinetosis than SS3.

3. Kinetosis to the extent of vomiting caused the volunteers to abandon task performance. In some cases tasks were abandoned before vomiting occurred.

4. Two subjects who neither vomited nor aborted were able to perform tasks throughout the entire series.

5. In all runs regardless of condition, which lasted for more than 2 hours, all subjects who vomited subsequently aborted the run, with one exception (#59, 9/22/75, SS4A).

6. No subject voluntarily withdrew from a run for any reason other than motion sickness.

7. Recovery from the symptoms of kinetosis began promptly with cessation of motion. However, some symptoms did not fully resolve for several hours.

8. No significant lasting pathologic changes were observed in any of the subjects because of kinetosis.

9. Measurements of the inertial input to the head may be a more reliable means of predicting kinetosis than measurement of vehicular inertial inputs. Head inertial response information from Phase II has not yet been analyzed for the purposes of evaluating this hypothesis.

10. The standard score of vestibular function testing used during the selection process for these subjects was marginally related to susceptibility to heave induced motion sickness and therefore is an unreliable predictor in its current form.

11. The data presented show no evidence of subject habituation to the motion to which they were exposed.

12. On those runs lasting more than 6 hours, approximately 50% of those vomiting did so for the first time after 6 hours.

13. The incidence of emesis did not appear to be affected by sleep assignments.

RECOMMENDATIONS

There are five general approaches to the problem of limiting the incidence of kinetosis on operational naval vehicles. These are:

1. Crew selection of personnel who are resistent to motion sickness.

2. Preventive treatment for kinetosis.

3. Adaptation (habituation) of crew to motion condition.

4. Modification of motion experienced by the crew through engineering design.

5. Limitation of operation of the vehicle during the more severe sea states.

The order of listing of these approaches does not imply which should be given priority in any application. Crew selection procedures have not been developed. Preventive treatment has been used for various types of motion sickness but has not been evaluated systematically for heave motion and may have unacceptable side effects. Adaptation though possible in the majority of cases for sinusoidal motion has not been shown to be practical for complex ship motion. Modification of the motion by engineering design requires a specification validated by human response data which is not yet available. Limitation of operation of the vehicle requires valid criteria and may materially reduce the effectiveness of the ship system. An optimal selection of approaches and the specification for each cannot be made at this time due to the lack of human data, which lack will impede utilization of naval weapons systems which induce motion sickness. Therefore, it is recommended that pertinent and reliable human data be collected in a systematic way on a high priority basis.

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	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S
CREWS A & B (JULY)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2
CREWS C & D (AUGUST)	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
CREWS E & F (SEPTEMBER)	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
CREW A C E	Travel to Santa Barbara	TASK TRAINING			BRIEFING	COND 0	MAINTENANCE		COND. 1	MAINTENANCE		COND. 0	MAINTENANCE		COND. 2	MAINTENANCE		COND. 0	MAINTENANCE		COND. 3	COND. 0						
CREW B D F						FREE			COND. 0			COND. 1			COND. 0			COND. 2			COND. 0	Maintenance		COND. 3		COND. 0	DEBRIEF	TRAVEL

	CONDITIONS
0	Stationary in control cabin.
1	Sea State 3, 80 knots (RMS g 0.19)
3	Sea State 4, 60 knots (RMS g 0.25)
4	Sea State 5, 40 knots (RMS g 0.28)

Fig. 1 Revised schedule for crews C and F only, from SESPC - Refer to next page

	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su
CREWS A & B (JULY)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3
CREW A																	MAINTENANCE	COND. 0		MAINTENANCE	COND. 2		MAINTENANCE	COND. 0				COND. 0
CREW B															COND. 1	COND. 0		COND. 2		MAINTENANCE	COND. 0		MAINTENANCE	COND. 3		COND. 0	DEBRIEF	DEPART	

	CONDITIONS
0	Stationary in control cabin.
1	Sea State 3, 80 knots (RMS g 0 19)
2	Sea State 4, 60 knots (RMS g 0.25)
3	Sea State 5, 40 knots (RMS g 0.28)

NOTE

(a) All simulation periods static or motion will start and finish at 1000, except where a change of cabin is indicated without a break. On these occasions runs will be terminated at 0900 and recommence as soon as cabins have been replenished.

Fig. 1 Revised schedule for crews A and B only, from SESPO

Date	Planned Condition	Planned Duration	Actual Duration	Subject	Emesis	Time of First Emesis	Number of Episodes	Abort	Elapsed Time to Abort	Remarks
7/14/75	SS3	48h	9h05m	44 49	No No			No No		Simulator failure terminated run.
7/20 - 7/21/75	SS3	24h	23h50m	47 52	Yes No	1h23m	10	Yes No	23h10m	
7/21 - 7/22/75	SS3	24h	24h	44 49 38	Yes No No	3h37m	2	Yes No No	7h07m	Replaced by 38. Only one heave pump operating.
7/23/75	SS4	24h	8h28m	47 52 46	No Yes No	6h37m	2	No Yes No	7h21m	Replaced by 46. Only exposed to 30 seconds of motion prior to simulator failure.
7/26/75	SS4	24h	9h	47 49	Yes Yes	7h18m 5h41m	1 2	Yes Yes	7h20m 9h	
7/28 - 7/29/75	SS4 70%	23h	23h	38 46	No No			No No		
7/29 - 7/30/75	SS4 70%	23h	23h	47 49	Yes No	11h32m	1	Yes No	11h32m	
7/30 - 7/31/75	SS3	23h	14h54m	38 46	No No			Yes Yes	2h33m 14h54m	Severe nausea. Severe nausea.
7/31 - 8/1/75	SS3	23h	23h	49 35	No No			No No		
8/10/75	0.3Hz 0.19G	2h	2h06m	51 50 48	No Yes Yes	15m 16m	5 3	No Yes Yes	58m 23m	
8/10/75	0.3Hz 0.19G	2h	2h	43 39	No No			No No		

Fig. 2 Chronological Tabulation of Human Subject Experiments for Phase II (7/14/75 through October 2, 1975) - Refer to next page

Date	Planned Condition	Planned Duration	Actual Duration	Subject	Emesis	Time of First Emesis	Number of Episodes	Abort	Elapsed Time to Abort	Remarks
8/11/75	0.3Hz 0.19G	2h	1h49m	51 50 48	No Yes Yes	 36m 51m	 1 1	No Yes No	 37m	
8/11/75	0.3Hz 0.19G	2h	2h	43 39	No Yes	 1h50m	 1	No No		
8/12/75	0.3Hz 0.19G	2h	1h42m	51 50 48	No No Yes	 56m	 2	No Yes Yes	 42m 1h08m	Approximately 16m of no motion. Severe nausea.
8/12/75	0.3Hz 0.19G	2h	2h	43 39	No No			No No		
8/16 - 8/18/75	SS3 80%	48h	47h	50 43	No No			No No		Drive signal doubly attenuated in error, i.e. 80% of 80%. Actual level = 64%
8/19 - 8/21/75	SS3 80%	48h	48h	39 48	No No			No No		Drive signal doubly attenuated in error, i.e. 80% of 80%. Actual level = 64%.
8/22/75	SS3	48h	22h50m	50 43	No No			No No		Power failure led to early termination.
8/25 - 8/27/75	SS3	48h	42h51m	39 48 51	No Yes No	 11h04m	 3	No Yes No	 11h58m	Replaced by 51. Approximately 6h delay during run because of mechanical problems.
8/29 - 8/31/75	SS5	48h	33h19m	50 48 43	No Yes No	 35m	 2	Yes Yes No	1h08m 46m	Severe nausea. Replaced by 48. Self induced emesis post run. Run shortened because of start-up delay Only one heave pump operating.
9/1 - 9/2/75	SS5	48h	23h16m	51 39 58 43	No Yes Yes No	 10h30m 24m	 7 6	No Yes Yes No	 16h23m 2h47m	Only one heave pump operating. Replaced by 58. Replaced by 43. Run terminated early because of mechanical failure of simulator.

Fig. 2 (Continued) - Refer to next page

Date	Planned Condition	Planned Duration	Actual Duration	Subject	Emesis	Time of First Emesis	Number of Episodes	Abort	Elapsed Time to Abort	Remarks
9/10/75	SS3	2h	2h	56 60 59	No No No			No No No		
9/10/75	SS3	2h	2h	40 57 61	No Yes No	44m	2	No No No		
9/11/75	SS4	2h	2h	56 60 59	No No No			No No No		
9/11/75	SS4	2h	2h	40 57 61	No Yes Yes	59m 45m	1 1	No No No		
9/12/75	SS5	2h	2h	56 60 59	Yes Yes Yes	1h02m 1h18m 59m	1 2 1	No No No		
9/12/75	SS5	2h	1h55m	40 61	No Yes	31m	2	No Yes	42m	
9/16 - 9/18/75	SS3	48h	46h53m	60 40	No No			No No		Run terminated early by duty test director.
9/19 - 9/21/75	SS3	48h	48h	61 56	No No			No No		
9/22/75	SS4A	6h	6h	43 59	No Yes	2h23m	1	No No		rms attenuated to 0.19G.
9/22/75	SS4A	6h	6h	51 40	No No			No No		rms attenuated to 0.19G. Severe nausea after 1h27m; persisted about 3h.

Fig.2 (Continued) - Refer to next page

Date	Planned Condition	Planned Duration	Actual Duration	Subject	Emesis	Time of First Emesis	Number of Episodes	Abort	Elapsed Time to Abort	Remarks
9/23/75	SS4A	6h	5h51m	60 56	No No			No No		rms attenuated to 0.19G.
9/23/75	SS4A	6h	4h23m	57 61	Yes Yes	54m 4h15m	2 2	Yes Yes	4h23m 4h23m	rms attenuated to 0.19G.
9/24/75	SS5A	6h	6h	43 59	No Yes	1h06m	2	No Yes	1h07m	rms attenuated to 0.19G.
9/24/75	SS5A	6h	6h	51 40	No No			No No		rms attenuated to 0.19G.
9/25/75	SS5A	6h	6h	60 56	No Yes	2h42m	1	No Yes	2h42m	rms attenuated to 0.19G.
9/26/75	SS4	6h	6h	43 60	No No			No No		
9/26/75	SS4	6h	6h	51 40	No No			No No		
9/27/75	SS5	6h	6h	43 60	No No			No No		
9/27/75	SS5	6h	6h	51 [illegible]	No Yes	2h19m		No Yes	2h20m	
9/29 - 10/1/75	SS5	48h	48h	43 51	No No			No No		
10/2/75	SS4	48h	12h55m	60 40	Yes Yes	8h36m 12h30m	2 5	Yes Yes	9h12m 12h55m	

Fig. 2 (Continued and Concluded)

Date of Presentation	Number of Recruits for Presentation	Number of Recruits Interviewed	Volunteer Candidates	Qualified Volunteers
4/2/74	101	25	16	3
4/22/74	95	42	24	4
6/17/74	60	26	15	5
9/23/74	94	34	24	2
1/14/75	181	67	33	6
4/23/75	69	21	12	6
TOTAL	600	215	124	26

Fig. 3 Numerical summary of human volunteer recruitment effort

SUBJECT No.	VARIATIONS FROM NORMAL
H035	1. Susceptibility for visual-vestibular conflict motion sickness susceptibility may be high
H038	1. High frequency neurosensory hearing loss combined with poor speech discrimination may result in difficulty in inte preting multiple message inputs.
H039	1. Incomplete auditory studies indicate some high frequency neurosensory deficit at 3 and 4 KHz. 2. Grade 2/6 systolic ejection murmur noted. 3. Sinus arrythmia noted on electrocardiogram. 4. Atopic rhinitis. 5. Nasal septal deviation to right, airway borderline adequate. 6. 20/30 bilaterally correctable to 20/20. 7. Alkaline phosphatane (Alk.Phos.) 90 mu/ml (milliunits per milliliter) [normal 30 - 85 mu/ml]
H040	1. Borderline blood chemistry results: a. 2 hour post prandial blood glucose 154 mg/100 ml (milligrams per 100 milliliters (normal = less than 145 mg/100 ml) b. Albumin 5.10 (normal 3.5 to 5.0 gm/100 ml) (grams per 100 milliliters) c. Calcium 11.40 mg/100 ml (normal 8.5 to 10.50 mg/100ml) d. Iron 191 mcg/100 ml (normal 45 to 150 mcg/100 ml) (micrograms per 100 milliliters)
H043	1. Ossicular discontinuity with high frequency conductive hearing loss at 6 KHZ. 2. Hypoplastic neural arch of C1 posteriorly.
H044	1. Severe bilateral hearing loss above 2 KHz and decreased speech discrimination. 2. Visual acuity 20/100 both eyes correctable to 20/20.
H046	1. Very mildly disordered electroencephalogram due to excessive slowing for age. Indeterminate waking trace. 2. Scratchy grade 2/6 systolic ejection murmur. 3. Trace of pretibial edema. 4. Visual acuity 20/40 right eye, 20/50 left eye, correctable to 20/20 both eyes. 5. Slight atopic decrease in hearing at 8KHz. 6. Mild atopic rhinitis. 7. Oculo-gyru illusion (OGI) is below normal limits. 8. Allergic to penicillin.
H047	NONE
H048	1. Right exotropia.
H049	1. Decreased hearing at 4 KHz both ears. 2. Elevated Creatinine Phosphokinase (CPK) of 224 units and normals not given. Evaluation shows no related abnormality.
H050	1. Mildly obstructive pulmonary function examination. 2. Visual acuity 20/30 right eye, 20/40 left eye, correctable to 20/20 both eyes. 3. Elevated Alkaline Phosphatase 158 mu/ml and creatinine phosphokinase 184 mu/ml (normal 0 - 70 mu/ml)

Fig 4 Summary of qualification examination results

SUBJECT NO.	VARIATIONS FROM NORMAL
H051	1. Defective color vision. 2. Visual acuity 20/25 both eyes, correctable to 20/20 both eyes. 3. Herniation of lateral head of triceps, right arm. 4. Nasal septal deviation to right, no obstruction.
H052	1. Borderline obstructive airway disorder, forced expiratory volume/vital capacity (72-81%), decreased minute expiratory flow rate 3.74 l/s (liters per second) (normal = 54 ± 1.4 l/s) 2. Coronary sinus mechanism with change of "P" wave noted on electrocardiogram and vectorcardiogram.
H056	1. Grade 1/6 systolic ejection murmur at apex of heart. 2. Sinus arrythmia with some wondering of atrial pacemaker. 3. Grade 1/6 mid epigastrium systolic bruit. 4. Acne vulgaris. 5. Amputation of part of fourth right finger.
H057	1. Visual acuity 20/25 both eyes, correctable to 20/20 both eyes.
H058	1. Grade 1/6 apical systolic ejection murmur. 2. Slight nasal septal deviation to left without obstruction. 3. Visual acuity 20/40 both eyes, correctable to 20/20 both eyes.
H059	1. Grade 1/6 mid-systolic ejection murmur. 2. Slight narrowing of intervertebral space between the 4th and 5th cervical vertebrae. 3. Slight neurosensory hearing loss left ear ; slight conductive hearing loss right ear.
H060	1. Functional systolic murmur. 2. Visual acuity 20/100 both eyes corrected to 20/20.
H061	1. Slight decreases in speech discrimination in right ear. 2. Molluscum contagiosum of right hand. 3. Schmorl's nodes in lumbar spine.

Fig 4 (Cont'd) Summary of qualification examination results

Subject	Date	Planned Condition	Planned Duration	Actual Duration	Emesis	Time of First Emesis	Number of Episodes	Abort	Elapsed Time to Abort	Remarks
57	9/10/75	SS3	2h	2h	Yes	44m	2	No		
	9/11/75	SS4	2h	2h	Yes	59m	1	No		
	9/23/75	SS4A	6h	4h23m	Yes	54m	2	Yes	4h23m	rms attenuated to 0.19G.
47	7/20 - 7/21/75	SS3	24h	23h50m	Yes	1h23m	10	Yes	23h10m	
	7/23/75	SS4	24h	8h28m	No			No		
	7/26/75	SS4	24h	9h	Yes	7h18m	1	Yes	7h20m	
	7/29 - 7/30/75	SS4	23h	23h	Yes	11h32m	1	Yes	11h33m	
38	7/21 - 7/22/75	SS3	24h	24h	No			No		
	7/28 - 7/29/75	SS4	23h	23h	No			No		
	7/30 - 7/31/75	SS3	23h	14h54m	No			Yes	2h33m	Severe nausea.
44	7/14/75	SS3	48h	9h05m	No			No		Simulator failure terminated run.
	7/21 - 7/22/75	SS3	24h	24h	Yes	5h37m	2	Yes	7h07m	Replaced by 38. Only one heave pump operating.
48	8/10/75	0.3Hz 0.19G	2h	2h06m	Yes	16m	3	Yes	23m	
	8/11/75	0.3Hz 0.19G	2h	1h49m	Yes	51m	1	No		
	8/12/75	0.3Hz 0.19G	2h	1h42m	Yes	56m	2	Yes	1h08m	

Fig. 5 Tabulation of the human subject experiments for Phase II organized by subject. The subjects are listed in increasing order of resistance to kinetosis
(Refer to next page)

Subject	Date	Planned Condition	Planned Duration	Actual Duration	Emesis	Time of First Emesis	Number of Episodes	Abort	Elapsed Time to Abort	Remarks
48 (Cont'd)	8/19 - 8/21/75	SS3 80%	48h	48h	No			No		Drive signal doubly attenuated in error i.e. 80% of 80%. Actual level=64%.
	8/25 - 8/27/75	SS3	48h	42h51m	Yes	11h04m	3	Yes	11h58m	Replaced by 51. Approx. 6h delay during run because of mechanical problems.
	8/29 - 8/31/75	SS5	48h	33h19m	Yes	35m	2	Yes	46m	Replacement for subject 50. Run shortened because of start-up delay. Only one heave pump operating.
46	7/23/75	SS4	24h	8h28m	No			No		Replacement for 52. Only exposed to 30 seconds of motion prior to simulator failure.
	7/28 - 7/29/75	SS4 70%	23h	23h	No			No		
	7/30 - 7/31/75	SS3	23h	14h54m	No			Yes	14h54m	Severe nausea.
59	9/10/75	SS3	2h	2h	No			No		
	9/11/75	SS4	2h	2h	No			No		
	9/12/75	SS5	2h	2h	Yes	59m	1	No		
	9/22/75	SS4A	6h	6h	Yes	2h23m	1	No		rms attenuated to 0.19G.
	9/24/75	SS5A	6h	6h	Yes	1h06m	2	Yes	1h07m	rms attenuated to 0.19G
61	9/10/75	SS3	2h	2h	No			No		
	9/11/75	SS4	2h	2h	Yes	45m	1	No		
	9/12/75	SS5	2h	1h55m	Yes	31m	2	Yes	42m	
	9/19 - 9/21/75	SS3	48h	48h	No			No		
	9/23/75	SS4A	6h	4h23m	Yes	4h15m	2	Yes	4h23m	rms attenuated to 0.19G.

Fig. 5 (Continued)

Page 2

Subject	Date	Planned Condition	Planned Duration	Actual Duration	Emesis	Time of First Emesis	Number of Episodes	Abort	Elapsed Time to Abort	Remarks
49	7/14/75	SS3	48h	9h05m	No			No		Simulator failure terminated run.
	7/21 - 7/22/75	SS3	24h	24h	No			No		Only one heave pump operating
	7/26/75	SS4	24h	9h	Yes	5h41m	2	Yes	9h	
	7/29 - 7/30/75	SS4 70%	23h	23h	No			No		
	7/31 - 8/1/75	SS3	23h	23h	No			No		
52	7/20 7/21/75	SS3	24h	23h50m	No			No		
	7/23/75	SS4	24h	8h28m	Yes	6h37m	2	Yes	7h21m	Replaced by 46.
60	9/10/75	SS3	2h	2h	No			No		
	9/11/75	SS4	2h	2h	No			No		
	9/12/75	SS5	2h	2h	Yes	1h18m	2	No		
	9/16 - 9/18/75	SS3	48h	46h53m	No			No		Run terminated early by duty test director.
	9/23/75	SS4A	6h	5h51m	No			No		rms attenuated to 0.19G
	9/25/75	SS5A	6h	6h	No			No		rms attenuated to 0.19G
	9/26/75	SS4	6h	6h	No			No		
	9/27/75	SS5	6h	6h	No			No		
	10/2/75	SS4	48h	12h55m	Yes	8h36m	2	Yes	9h12m	
40	9/10/75	SS3	2h	2h	No			No		
	9/11/75	SS4	2h	2h	No			No		
	9/12/75	SS5	2h	2h	No			No		

Fig. 5 (Continued)

Subject	Date	Planned Condition	Planned Duration	Actual Duration	Emesis	Time of First Emesis	Number of Episodes	Abort	Elapsed Time to Abort	Remarks
40 (Cont'd)	9/16 - 9/18/75	SS3	48h	46h53m	No			No		Run terminated early by duty test director.
	9/22/75	SS4A	6h	6h	No			No		rms attenuated to 0.19G. Severe nausea after 1h27m; persisted about 3h.
	9/24/75	SS5A	6h	6h	No			No		rms attenuated to 0.19G.
	9/26/75	SS4	6h	6h	No			No		
	9/27/75	SS5	6h	6h	Yes	2h19m		Yes	2h20m	
	10/2/75	SS4	48h	12h55m	Yes	12h30m	5	Yes	12h55m	
56	9/10/75	SS3	2h	2h	No			No		
	9/11/75	SS4	2h	2h	No			No		
	9/12/75	SS5	2h	2h	Yes	1h02m	1	No		
	9/19 - 9/21/75	SS3	48h	48h	No			No		
	9/23/75	SS4A	6h	5h51m	No			No		rms attenuated to 0.19G.
	9/25/75	SS5A	6h	6h	Yes	2h42m	1	Yes	2h42m	rms attenuated to 0.19G.
50	8/10/75	0.3Hz 0.19G	2h	2h06m	Yes	15m	5	Yes	58m	
	8/11/75	0.3Hz 0.19G	2h	1h49m	Yes	36m	1	Yes	37m	
	8/12/75	0.3Hz 0.19G	2h	1h42m	No			Yes	42m	Severe nausea. Approx. 16m of no motion.
	8/16 - 8/18/75	SS3 80%	48h	47h	No			No		Drive signal doubly attenuated in error, i.e. 80% of 80%. Actual level = 64%.
	8/22/75	SS3	48h	22h50m	No			No		Power failure led to early termination.
	8/29 - 8/31/75	SS5	48h	33h19m	No			Yes	1h08m	Severe nausea. Replaced by 48. Run shortened because of start-up delay. Only one heave pump operating. Self induced emesis post run.

Fig. 5 (Continued)

Subject	Date	Planned Condition	Planned Duration	Actual Duration	Emesis	Time of First Emesis	Number of Episodes	Abort	Elapsed Time to Abort	Remarks
39	8/10/75	0.3Hz 0.19G	2h	2h	No			No		
	8/11/75	0.3Hz 0.19G	2h	2h	Yes	1h50m	1	No		
	8/12/75	0.3Hz 0.19G	2h	2h	No			No		
	8/19 - 8/21/75	SS3 80%	48h	48h	No			No		Drive signal doubly attenuated in error i.e. 80% of 80%. Actual level=o4%.
	8/25 - 8/27/75	SS3	48h	42h51m	No			No		Approx. 6h delay during run because of mechanical problems
	9/1 - 9/2/75	SS5	48h	23h16m	Yes	10h30m	7	Yes	16h23m	Only one heave pump operating. Replaced by 58. Run terminated early because of mechanical failure of simulator.
51	8/10/75	0.3Hz 0.19G	2h	2h06m	No			No		
	8/11/75	0.3Hz 0.19G	2h	1h49m	No			No		
	8/12/75	0.3Hz 0.19G	2h	1h42m	No			No		Approx. 16m of no motion.
	8/25 - 8/27/75	SS3	48h	42h51m	No			No		Replacement for subject 48. Approx. 6h delay during run because of mechanical problems.
	9/1 - 9/2/75	SS5	48h	23h16m	No			No		Only one heave pump operating. Run terminated early because of mechanical failure of simulator.
	9/22/75	SS4A	6h	6h	No			No		rms attenuated to 0.19G.

Fig. 5 (Continued)

Subject	Date	Planned Condition	Planned Duration	Actual Duration	Emesis	Time of First Emesis	Number of Episodes	Abort	Elapsed Time to Abort	Remarks
51 (Cont'd)	9/24/75	SS5A	6h	6h	No			No		rms attenuated to 0.19G.
	9/26/75	SS4	6h	6h	No			No		
	9/27/75	SS5	6h	6h	No			No		
	9/29 - 10/1/75	SS5	48h	48h	No			No		
43	8/10/75	0.3Hz 0.19G	2h	2h	No			No		
	8/11/75	0.3Hz 0.19G	2h	2h	No			No		
	8/12/75	0.3Hz 0.19G	2h	2h	No			No		
	8/16 - 8/18/75	SS3 80%	48h	47h	No			No		Drive signal doubly attenuated in error, i.e. 80% of 80%. Actual level = 64%.
	8/22/75	SS3	48h	22h50m	No			No		Power failure led to early termination.
	8/29 - 8/31/75	SS5	48h	33h19m	No			No		Run shortened because of start-up delay. Only one heave pump operating.
	9/1 - 9/2/75	SS5	48h	23h16m	No			No		Only one heave pump operating. Replacement for subject 58. Run terminated early because of mechanical failure of simulator.
	9/22/75	SS4A	6h	6h	No			No		rms attenuated to 0.19G.
	9/24/75	SS5A	6h	6h	No			No		rms attenuated to 0.19G.
	9/26/75	SS4	6h	6h	No			No		
	9/27/75	SS5	6h	6h	No			No		
	9/29 - 10/1/75	SS5	48h	48h	No			No		

Fig. 5 (Continued and Concluded)

	SUBJECT	SS3	SS4	SS5	SINE
JULY	47	⊖	+ ⊖ ⊖	N/E	N/E
	38	+ ⊕	+	N/E	N/E
	44	+ ⊖	N/E	N/E	N/E
	46	⊕	+	N/E	N/E
	49	+ + +	⊖ +	N/E	N/E
	52	+	⊖	N/E	N/E
	35	+	N/E	N/E	N/E
AUGUST	58	N/E	N/E	⊖	N/E
	48	+ ⊖	N/E	⊖	⊖ - ⊖
	50	+ +	N/E	⊕	⊖ ⊖ ⊕
	39	+ +	N/E	⊖	+ - +
	51	+	N/E	+	+ + +
	43	+ +	N/E	+ +	+ + +
SEPTEMBER	57	-	- ⊖	N/E	N/E
	59	+	+ -	- ⊖	N/E
	61	+ +	- ⊖	⊖	N/E
	60	+ +	+ + + ⊖	- + +	N/E
	40	+ +	+ + + ⊖	+ + ⊖	N/E
	56	+ +	+ +	- ⊖	N/E
	51	N/E	+ +	+ + +	N/E
	43	N/E	+ +	+ + +	N/E

Legend:

+ = Run completed without emesis or abort by subject
- = Run completed with at least one vomiting episode.
⊕ = Run aborted without vomiting.
⊖ = Run aborted due to vomiting.
N/E = Subject not exposed to this condition.

Notes:

1. Subjects are listed within each month in order of increasing resistance to kinetosis, except for 35 and 58 who were not ranked (see text).
2. Each symbol represents one subject in a run regardless of duration (23 minutes to 48 hours).
3. In each sea state, runs are listed chronologically from left to right.
4. In September, subjects 51 and 43 were re-exposed to SS5 and therefore appear in both August and September.
5. The sea state columns include all runs in that sea state regardless of attenuation.

Fig. 6 Incidence of vomiting and voluntary aborts by subjects in each run

Condition	July	August	Septembe	TOTALS
SS3*	2/7**	1/5	1/6	4/18 = 22%
SS4*	3/5	0/0	5/8	8/13 = 62%
SS5*	0/0	3/6	5/7	8/11** = 73%
0.3 Hz 0.19G	0/0	3/5	0/0	3/5 = 60%

* Refers to any amplitude level within the condition, ranging from 64% to 100% of the heave acceleration.

** Although the monthly totals in SS5 are correct, two individuals were re-exposed to SS5 in September, for a total of only 11 individuals.

Fig. 7 The ratio and percentage of the volunteers who vomited at some time during the condition

Condition	July	August	September	TOTALS
SS3*	4/7	1/5	1/6	6/18 = 33%
SS4*	3/5	0/0	5/8	8/13 = 62%
SS5*	0/0	4/6	5/7	9/11** = 82%
0.3 Hz 0.19G	0/0	3/5	0/0	3/5 = 60%

*Refers to any amplitude level within the condition, ranging from 64% to 100%.

** Although the monthly totals in SS5 are correct, two individuals were re-exposed to SS5 in September, for a total of only 11 individuals.

Fig. 8 The ratio and percentage of the volunteers who aborted with or without vomiting by conditions

Condition	Total Runs	Simulator Total Time	Total Runs w/ Emesis &/or Abort
SS3, 64%	2	95h	no emesis or aborts
SS3, one pump	1	24h	one run
SS3, 100%	10	235h23m	four runs
SS4, 70%	2	46h	one run
SS4A	4	22h14m	two runs
SS4, 100%	7	46h23m	four runs
SS5, one pump	2	56h35m	two runs
SS5A	3	18h	two runs
SS5, 100%	5	63h55m	three runs
Sine	6	11h23m	four runs
	42	618h53m	23 runs with either vomiting or aborts

Fig. 9 Summary of runs and running time

Subject Number	VVI		BVDT		MSQ	PATE		Sum Total Standard Score	Rank
	Rater	Self-Rate	Rater	Self-Rate		Rater	Self-Rate		
39	2.21	1.92	.93	2.47	1.50	1.23	1.11	11.37	15
57	.03	1.41	3:76	-.29	-.19	2.04	1.84	8.6	14
59	.38	.68	2.26	-.29	-.02	.24	-.06	3.19	13
38	.26	1.51	.26	-.17	-.36	0.57	.76	2.83	12
51	-1.00	.99	-.07	1.09	1.59	0.00	.06	2.66	11
49	-.88	-.15	-.23	1.32	-1.05	1.09	2.27	2.37	10
48	-.20	-.98	-1.26	.17	-.45	0.00	-.28	-.48	9
44	-1.00	-.25	-.23	-.17	1.31	-.25	-.11	-.7	8
40	-.77	-1.18	-.40	-.86	-1.05	2.04	.74	-1.48	7
52	.49	-.25	-.23	.98	-.76	-.82	-.84	-1.43	6
61	-.65	1.10	-.73	-.75	-1.05	-.25	-.76	-3.09	5
56	-1.00	-1.18	-.90	-.86	1.19	-.19	-.71	-3.65	4
60	-1.00	-.46	-.73	-.98	.13	-.51	-.28	-3.83	3
50	-.20	-1.08	-.40	-.86	-.32	-.82	-.71	-4.39	2
43	-.77	-1.08	-.23	-.86	-1.05	-.82	-.84	-5.65	1

Fig. 10 Ranking of New Orleans subjects by sum total of standard scores from 4 tests, from F. Guedry, NAMRL, Pensacola, Florida.

Time to 1st Emesis	Time to Abort	Subject	Date	Actual Condition
15m	58m	50 (3)	8/10/75	Sine Wave
16m	23m	48 (3)	8/10/75	Sine Wave
24m	2h47m	58 (1)	9/1 - 2/75	SS5
31m	42m	61 (3)	9/12/75	SS5
35m	46m	48 (2)	8/29 - 31/75	SS5
36m	37m	50 (3)	8/11/75	Sine Wave
None	42m	50 (3)	8/12/75	Sine Wave
44m	None	57 (3)	9/10/75	SS3
45m	None	61 (3)	9/11/75	SS4
51m	None	48 (3)	8/11/75	Sine Wave
54m	4h23m	57 (3)	9/23/75	SS4A
56m	1h08m	48 (3)	8/12/75	Sine Wave
59m	None	57 (3)	9/11/75	SS4
59m	None	59 (3)	9/12/75	SS5
1h02m	None	56 (3)	9/12/75	SS5
1h06m	1h07m	59 (3)	9/24/75	SS5A
None	1h08m	50 (2)	8/29 - 31/75	SS5
1h18m	None	60 (3)	9/12/75	SS5
1h23m	23h10m	47 (2)	7/20 - 21/75	SS3
1h50m	None	39 (3)	8/11/75	Sine Wave
2h19m	2h20m	40 (3)	9/27/75	SS5
2h23m	None	59 (3)	9/22/75	SS4A
2h42m	2h42m	56 (3)	9/25/75	SS5A
None	2h33m	38 (2)	7/30 - 31/75	SS3
4h15m	4h23m	61 (3)	9/23/75	SS4A
5h37m	7h07m	44 (2)	7/21 - 22/75	SS3
5h41m	9h0m	49 (1)	7/26/75	SS4
6h37m	7h21m	52 (1)	7/23/75	SS4
7h18m	7h20m	47 (2)	7/26/75	SS4
8h36m	9h12m	60 (2)	10/2/75	SS4
10h30m	16h23m	39 (1)	9/1 - 2/75	SS5
11h04m	11h58m	48 (2)	8/25 -27/75	SS3
11h32m	11h33m	47 (2)	7/29 -30/75	SS4
12h30m	12h55m	40 (1)	10/2/75	SS4
None	14h54m	46 (1)	7/30 - 31/75	SS3

(1) = Assigned night sleeper for the run.
(2) = Assigned day sleeper for the run.
(3) = Short run, less than 6 hours, without sleep cycle assigned for the run.

Fig. 11 Listing of times to first emesis